

of oxides in the electric arc are always carbides. There are, in fact, some of the rarer metals which we, as yet, can hardly be said to know except as carbides. As the following experiment is the last of the series, I would express my thanks to my assistant, Mr. Stansfield, for the great care he has bestowed in order to ensure their success. Here is the carbide of calcium which is produced by heating lime and carbon in the electric arc. It possesses great chemical activity, for if it is placed in water the calcium seizes the oxygen of the water, while the carbon also combines with the hydrogen, and acetylene is the result, which burns brilliantly. [Experiment shown.] If the carbide of calcium be placed in chlorine water, evil smelling chloride of carbon is formed.

In studying the relations of the rarer metals to iron, it is impossible to dissociate them from the influence exerted by the simultaneous presence of carbon; but carbon is a protean element—it may be dissolved in iron, or it may exist in iron in any of the varied forms in which we know it when it is free. Matthiessen, the great authority on alloys, actually writes of the “carbon-iron alloys.” I do not hesitate therefore, on the ground that the subject might appear to be without the limits of the title of this lecture, to point to one other result which has been achieved by M. Moissan. Here is a fragment of pig iron highly carburised: melt it in the electric arc in the presence of carbon, and cool the molten metal suddenly, preferably by plunging it into molten lead. As cast iron expands on solidification, the little mass will become solid at its surface and will contract; but when, in turn, the still fluid mass in the interior cools, it expands against the solid crust, and consequently solidifies under great pressure. Dissolve such a mass of carburised iron in nitric acid to which chloride of potash is added; treat the residue with caustic potash, submit it to the prolonged attack of hydrofluoric acid, then to boiling sulphuric acid, and finally fuse it with potash, to

These relate to the singular attitude towards metallurgical research maintained by those who are in a position to promote the advancement of science in this country. Statements respecting the change of shining graphite into brilliant diamond are received with appreciative interest; but, on the other hand, the vast importance of effecting similar molecular changes in metals is ignored.

We may acknowledge that “no nation of modern times has done so much practical work in the world as ourselves, none has applied itself so conspicuously or with such conspicuous success to the indefatigable pursuit of all those branches of human knowledge which give to man his mastery over matter.”¹ But it is typical of our peculiar British method of advance to dismiss all metallurgical questions as “industrial,” and leave their consideration to private enterprise.

We are, fortunately, to spend, I believe, eighteen millions this year on our Navy, and yet the nation only endows experimental research in all branches of science with four thousand pounds. We rightly and gladly spend a million on the *Magnificent*, and then stand by while manufacturers compete for the privilege of providing her with the armour-plate which is to save her from disablement or destruction. We as a nation are fully holding our own in metallurgical progress, but we might be doing so much more. Why are so few workers studying the rarer metals and their alloys? Why is the crucible so often abandoned for the test-tube? Is not the investigation of the properties of alloys precious for its own sake, or is our faith in the fruitfulness of the results of metallurgical investigation so weak that, in its case, the substance of things hoped for remains unsought for and unseen in the depths of obscurity in which metals are still left?

We must go back to the traditions of Faraday, who was the first to investigate the influence of the rarer metals upon iron,



FIG. 8.—Preparations for the microscope of diamonds and other forms of carbon obtained from carburised iron.

remove any traces of carbide of silicon, and you have carbon left, but—in the form of *diamonds*.

If you will not expect to see too much, I will show you some diamonds I have prepared by strictly following the directions of M. Moissan. As he points out, these diamonds, being produced under stress, are not entirely without action on polarised light, and they have, sometimes, the singular property of flying to pieces like Rupert's drops when they are mounted as preparations for the microscope. [The images of many small specimens were projected on the screen from the microscope, and (Fig. 8, E) shows a sketch of one of these. The largest diamond yet produced by M. Moissan, is 0.5 millimetre in diameter.]

A (Fig. 8) represents the rounded, pitted surface of a diamond, and B a crystal of diamond from the series prepared by M. Moissan, drawings of which illustrate his paper.¹ The rest of the specimens, C to F, were obtained by myself by the aid of his method as above described. C represents a dendritic growth apparently composed of hexagonal plates of graphite, while D is a specimen of much interest, as it appears to be a hollow sphere of graphitic carbon, partially crushed in. Such examples are very numerous, and their surfaces are covered with minute round graphitic pits and prominences of great brilliancy. Specimen E (which, as already stated, was one of a series shown to the audience) is a broken crystal, probably a tetrahedron, and is the best crystallised specimen of diamond I have as yet succeeded in preparing. Minute diamonds, similar to A, may be readily produced, and brilliant fragments, with the lamella structure shown in F, are also often met with.

The close association of the rarer metals and carbon and their intimate relations with carbon, when they are hidden with it in iron, enabled me to refer to the production of the diamond, and afford a basis for the few observations I would offer in conclusion.

and to prepare the nickel-iron series of which so much has since been heard. He did not despise research which might possibly tend to useful results, but joyously records his satisfaction at the fact that a generous gift from Wollaston of certain of the “scarce and more valuable metals” enabled him to transfer his experiments from the laboratory in Albemarle Street to the works of a manufacturer at Sheffield.

Faraday not only began the research I am pleading for to-night, but he gave us the germ of the dynamo, by the aid of which, as we have seen, the rarer metals may be isolated. If it is a source of national pride that research should be endowed apart from the national expenditure, let us, while remembering our responsibilities, rest in the hope that metallurgy will be well represented in the Laboratory which private munificence is to place side by side with our historic Royal Institution.

ELECTRICITY AND OPTICS.

A MEMOIR of singular interest, and one of which it would be well if the contents could be made more readily accessible to students in this country, has lately been published by Prof. Righi.² Among the numerous papers published during the last twenty years by Prof. Righi there are several (on electric discharges, on electric shadows and photo-electric phenomena) which indicate his interest in the relations between light and electricity. Since Hertz succeeded in obtaining rays of electric force, and demonstrated the reflection, refraction and interference of electric radiation, other experimenters have endeavoured to extend and complete the analogy between electromagnetic and luminous vibrations. Thus Lodge and Howard showed that electric radiation could be concentrated by means of large lenses;

¹ *The Times*, February 22, 1895.

² “Sulle oscillazioni elettriche a piccola lunghezza d'onda e sul loro impiego nella produzione di fenomeni analoghi ai principali fenomeni dell'ottica.” (Bologna: 1894).

¹ *Comptes rendus*, vol. cxviii., 1894, p. 324.

Boltzmann appears to have performed an experiment similar to Fresnel's with inclined mirrors; Trouton has drawn attention to phenomena similar to those of thin plates; and others have experimented with wire gratings like those by means of which Hertz demonstrated the polarisation of electric radiation: but the great wave-length (about half a metre) of the oscillations used has been a stumbling-block in the way of more delicate experiments. Prof. Righi has succeeded in producing oscillations having a wave-length as small as 2.6 cm., and has devised a novel form of resonator made by taking a strip of silvered glass, dissolving away the varnish from the back, and drawing a diamond-line across. He has thus been able to demonstrate the analogy with other phenomena of optics, among which may be mentioned:—Fresnel's interference-experiments with inclined mirrors and biprism; interference by reflection from thin plates and by transmission through them; diffraction by various means (slits, edges, Fresnel's diaphragm); elliptic and circular polarisation; and total reflection. The description of the experiments is accompanied with full theoretical discussions; and if Prof. Righi does not aim at the general treatment which is suitable to a treatise like Poincaré's, he, at any rate, succeeds admirably in showing how the border-land between electricity and optics is being actually explored.

In another memoir,¹ Prof. Righi develops Hertz's equations so as to find the electromagnetic disturbance produced by the combination of two small rectilinear electric oscillations at right angles, say along the axes of x and y , having equal amplitudes but differing in phase by a quarter wave-length. Each of these might be replaced by the mechanical movement of equal and opposite electric charges, oscillating with pendular motion about the origin along one of the axes. Two such mechanical motions at right angles, differing in phase by a quarter wave-length, would compound into a motion of uniform rotation in a circle about the origin in the plane of xy . The disturbance due to such a circular motion of equal and opposite charges would, with certain limitations, be the same as the disturbance produced by the combination of the two rectilinear oscillations first considered. Prof. Righi shows that it takes the form of a spherical wave having its centre at the origin of coordinates. The vibrations are in general (to use the language of optics) elliptically polarised; in the neighbourhood of the axis of x they are circularly polarised; in the equatorial plane xy they are plane-polarised.

In a third memoir, by Prof. H. A. Lorentz,² an attempt is made to establish a theory of electrical and optical phenomena in connection with moving bodies. This naturally involves a discussion of the relation between the ether and ponderable bodies in motion, and of the theories proposed by Fresnel and Stokes respectively. After weighing the evidence on both sides, the Leyden professor is of opinion that Fresnel's conception offers fewer difficulties than its rival. The question is of importance in electricity as well as in optics; it is necessarily raised by a rigid examination of any electrical phenomenon, such as the motion of a charged body or of a conductor carrying a current. Prof. Lorentz bases his explanation of electrical phenomena on the hypothesis that all bodies contain small electrically charged particles, and that all electrical processes depend upon the position and motion of these "ions." This conception of ionic charges is universally accepted for electrolytes, and also forms the most probable explanation of the convective discharge of electricity in gases. It is here extended to ponderable dielectrics, the "polarisation" of which is ascribed to the existence of such particles in positions of equilibrium from which they can only be displaced by external electrical forces. The periodically changing polarisations which, according to Maxwell's theory, constitute light-vibrations, here become vibrations of the ions.

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SCIENCE IN THE MAGAZINES.

A MOST interesting account of Madame Kovalevsky's eventful life is contributed to the *Fortnightly* by Mr. E. W. Carter. The sketch is based upon that gifted mathematician's own published recollections, and Madame Edgren-Leffler's biography of her lamented friend. As there are some who are not familiar with the career of the subject of Mr. Carter's article, a

short summary of the chief points may be of interest. Sophie Kovalevsky was born at Moscow about 1850, where the first five years of her life were spent. Her father then removed to Palibino, in the government of Vitebsk. It was there that her bent for mathematics first showed itself. A room had been papered with old disused printing paper, amongst which were several sheets of Ostrogradski's lectures on the differential and integral calculus. "This room possessed a strong fascination for the little seven-year-old maiden. Here she was to be found daily, her attention riveted on these walls, striving to understand something of the strange figures and stranger formulas. 'I remember,' says Madame Kovalevsky, 'that every day I used to spend hours before these mysterious walls, struggling to understand some of the sentences, and to find the order of the sheets. By dint of long contemplation, some of the formulas became firmly fixed in my memory, and even the text, though I could comprehend nothing of it at the time, left its impression on my brain.' When several years later, her father was prevailed on to let her have some instruction in mathematics, the results were a surprise and a revelation to all concerned; not least to the little pupil herself. The mysteries of the walls now grew clear, and her progress was made by leaps and bounds. The differential calculus presented no difficulties to her, and her tutor found that she knew the formulas by heart, and arrived at solutions and explanations quite independent of his aid."

In October, 1868, Sophie Kroukovsky contracted the romantic marriage with Vladimir Kovalevsky, and the two went to Heidelberg as students at the University. After two terms spent at Heidelberg, she moved to Berlin, where she worked for four years under the direction of Prof. Weierstrasse, "the father of modern mathematical analysis." During this period, she was occupied in writing the three important treatises which subsequently gained for her the degree of Doctor in Philosophy at Göttingen. Passing over the next few years in Madame Kovalevsky's life, during which her husband died, we come to the winter of 1883-84, when she went to Stockholm as the "Docent" of Prof. Mittag-Leffler. A course of lectures delivered during the winter session led to her appointment to the chair of higher mathematics at the University of Stockholm, in July, 1884, a post which she occupied until her death. The crowning scientific labour of her life was the treatise which gained for her the Bordin prize of the Paris Academy in 1888. The subject proposed was "To perfect in one important point the theory of the movement of a solid body round an immovable point," and in recognition of the extraordinary merits of Mme Kovalevsky's work, the judges raised the amount of the prize from three thousand to five thousand francs. But the distinguished authoress did not live many years to enjoy the high position she had gained. In February, 1891, she was attacked by an illness which ended fatally after three or four days. So passed away a woman of magnificent gifts, who, "Taking the direction of her life into her own hands, and choosing for herself one of the steepest paths to fame, she traversed it with swift and steady steps."

Mr. W. H. Hudson contributes to the *Fortnightly* an article on "The Common Crow," a bird which he finds from inquiries, "is no longer to be found as a breeder, or is exceedingly rare, in districts where game is very strictly preserved; but that in the wilder counties where game is not strictly preserved, in wooded hilly places, he still exists in diminished numbers as a breeding species." Another article in the same magazine, on "Danish Butter Making," by Mrs. Alec Tweedle, furnishes instructive reading for British agriculturists.

The remarkable growth of electric railroad mileage in the United States, during the past five years, is brought out in an article by Mr. Joseph Wetzler, in *Scribner*. "At the present time," he says, "there are over eight hundred and fifty electric railways in the United States, operating over 9000 miles of track and 23,000 cars, and representing a capital investment of over four hundred million dollars. What stupendous figures, when we consider that in 1887 the number of such roads amounted to only thirteen, with scarcely one hundred cars!" A quotation from a paper in the series on "The Art of Living," contributed by Mr. Robert Grant to the same magazine, is worth giving here. "There are signs that those in charge of our large educational institutions all over the country are beginning to recognise that ripe scholarship and rare abilities as a teacher are entitled to be well recompensed pecuniarily, and that the breed of such men is likely to increase somewhat in proportion to the size and number of the prizes offered. Our college presidents and

¹ "Sulle onde elettromagnetiche generate da due piccole oscillazioni elettriche ortogonali oppure per mezzo di una rotazione uniforme." (Bologna: 1894).

² "Versuch einer Theorie der elektrischen und optischen Erscheinungen in bewegten Körpern." (Leyden: 1895).